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A Mini-computer in a Senior Modern Physics Laboratory

Leonard Finegold
Department of Physics and Astrophysics
University of Colorado
Boulder, Colorado 80302

ABSTRACT

A mini-computer was recently introduced in a senior modern physics laboratory. Operating in a conversational mode, it has been an excellent way both of teaching students computing and of encouraging them to routinely use a computer. The choice of computer languages is discussed, and the advantages and possible disadvantages of a mini-computer are listed.

(Submitted for publication)

INTRODUCTION

The Senior Modern Physics Laboratory, taken by our graduating physics and engineering physics majors, recently acquired a mini-computer of 4096 word memory, 12-bit word length, and 1.6 usec cycle time [1]. The computer was purchased with an analogue-to-digital converter and oscilloscope display for use primarily as a multi-channel pulse-height analyzer, but it has now seen much service as a straight-forward computer. This paper describes an experience of interfacing students with the computer: while not greatly original nor done under the conditions of a controlled experiment, it is hoped that this account will be of interest to people in charge of similar laboratories.

THE COURSE

A few words about the course will set the background. The course meets formally for three hours a week for two hours credit. In an attempt to have a high instructor/student ratio, there is one instructor (a graduate student teaching assistant) to 6-8 students, and one faculty member in the laboratory or on call. The laboratory is also open several afternoons a week. The laboratory is extremely well equipped (thanks to a succession of N.S.F. grants and keen faculty members) and much of the apparatus would do credit to a research laboratory. The students are expected, in general, to do a series of varied experiments. Several of the nuclear counting experiments, in particular those using a commercial multi-channel pulse-height analyzer, can generate much data to be calculated, and hence have generated many complaints from students in the past.

COMPUTER LANGUAGE

A vexing problem was the choice of which computer language would be most suitable for th- students' calculations. Because of boundary conditions of the amount of physics to be covered in the course, and of the need for students to learn as quickly as possible how to use the computer, not more than two weeks could be allowed to each student for the computer. The optimal language, considering ease of learning and widespread use outside the laboratory, is probably BASIC [2] [3]. However, the University computer services (using CDC 6400) and most formal computer courses here, are based on FORTRAN programs. It was decided to have all the students to learn FOCAL (the PDP's own language) because (1) more of the computer memory was available for computing than with PDP-BASIC or PDP-FORTRAN, due to

the space occupied by the compilers (2) FOCAL is probably easier to learn than BASIC or FORTRAN at least in the 4K word versions (3) it seems that it is quite easy to learn BASIC or FORTRAN once one has learned FOCAL, and vice versa.

INSTRUCTION

Students were given explanatory sheets, told to read and work through the FOCAL manual [4] with a pencil and paper, and to prepare some easy programs -- to take an evening or so of their time. Suggested programs were least square fits to a straight line or to simple polynomials, location of a peak by its centroid, and plotting graphs of analytical expressions on the typewriter. In pairs for each laboratory period, they were then shown the mechanics of using the computer, typewriter, tape punch and tape reader: the FOCAL programs was kept in the memory to save loading time. The students were then left to try out the programs they had written. The instructors answered questions or helped if a student were obviously in difficulty. Bevington's text [5] contains specimen programs, and was quite useful.

Suprprisingly, even though several students had previously taken and passed a one credit-hour course in FORTRAN, they often behaved as though they had hardly been exposed to computing. Upon questioning, it became clear that in a conventional FORTRAN course, a student might have made only a few passes at the computer (our large computer at present only operates in a batch processing mode). However, most students were quite adept by the end of a class period on the mini-computer. The slowest students required nearly two periods (i.e., approximately 3 hours total on the machine). The class even included one professional programmer, who enjoyed the small machine.

As semester progressed, students did indeed routinely use the computer for calculating their laboratory results. Some became infected with "computer virus" and would spend much time in writing and correcting a program which would have taken less total time on a slide-rule or on the laboratory electro-mechanical calculator.

Presumably, exposure will confer immunity. (A slide rule, labeled "Analogue Computer", was left on the mini-computer). Although FOCAL was the language preferred in the laboratory, arrangements were made for students to also use, at their choice, the University CDC 6400 machine (in FORTRAN), or FORTRAN or BASIC on the mini-computer. An inexpensive magnetic

tape cassette system [6] loaded the complete memory in a minute, as compared with 20-30 minutes for the low-speed paper tape reader. Some of the engineering physics majors used conversational BASIC on a "Nova" computer in the Elec--rical Engineering department. Several students had access to a giant computer (CDC 6400 at the National Centre for Atmospheric Research) and presented their final experimental results with sophisticated computer-generated plots: Since they used computer routines written by others and did not check them, this may not be such a good regular procedure for a teaching laboratory.

ADVANTAGES OF A MINI-COMPUTER

The reader is reminded that the University Computer Services do not provide conversational mode computing. The mini-computer has the followingadvantages for introducing a student to computing, and encouraging him to write and use programs:

1) It operates in a convesational mode. The student receives results practically as fast as the typewriter can type. This is particularly good for getting the "feel" of a calculation.

2) The computer immediately informs the student of a programming error. Batch processing on the University machine may take 2 - 12 hours turnaround time, and can be discouraging to the student.

3) The typewritten input/output enables the student to read his complete calculation. He can also take the output a little way from the computer to peruse it while another student is using the computer, or read at leisure at home.

4) Paper tape is a cheap and reasonably convenient way for the student to store his own programs, and to enter them into the machine. For longer programs, it is faster to use the magnetic tape cassettes.

5) The MODIFY statement in FOCAL is very useful: a statement can easily be changed without having to retype the whole statement or to repunch a paper tape. This with (2) above is most important: To err is human [7].

6) The mini-computer is physically small, and under the complete control of the student, and so is approached with confidence by students who might be somewhat scared by a large piece of apparatus.

7) Unlike some time-sharing systems, the computer will run all night.

DISADVANTAGES OF A MINI-COMPUTER

To decide whether or not to buy a mini-computer is a difficult decision, but far more difficult is the problem of which mini-computer to buy. At present, mini-computers are improving rapidly, and actually becoming much cheaper with time, although a plateau will probably be reached with the introduction of integrated-circuit memories. Possible disadvantages of mini-computers are:

1) It may be cheaper to have a shared system to a large central computer. The cost analysis will depend, in part, on the cost and installation of communicating lines.

2) The mini-computer has a mini-memory. This has caused no real problems in the laboratory since, with a little ingenuity, one can usually divide a longer program into convenient sub-units, which are loaded as needed via paper tape or magnetic tape cassette. However, there might arise problems involving matrices of large dimension, which are more easily inverted on a machine with a larger memory. One has to weigh larger memories against their not inconsiderable cost - doubling the memory may cost almost as much again as did the mini-computer - and the usual availability of a larger machine.

3) In a centrally-operated system, the maintenance of the machine is the responsibility of experts. However, our computer has had only one failure - of an indicator light.

4) Although the mechanical typewriter is made only for a limited life, and has had minor problems, its life can be considerably extended by regular, careful maintenance. It is also noisy. Typewriters are available which produce less acoustical and electrical noise and which should require less maintenance, but they also are more expensive. (Incidentally, white paper is much easier to read than the usual yellow paper supplied with the typewriter.

5) To correct errors or change a program paper tape, the program must be loaded, corrected, and then a new paper tape produced, whereas with a punch card system only a few cards need be repunched. This could be an awkwardness with long programs.

SUMMARY

The mini-computer, operating in a conversational mode, is an excellent way both to introduce students to computing in a senior laboratory and to encourage them to use a computer routinely. It would be helpful to the students if they were given a formal lecture or two on numerical analysis, at the level of Bevington [5]. All too often students tend to do a complete problem, integrals and all, numerically on the computer, when a little algebra or the use of a book of standard series expansions or integrals would save much programming and computer time, and also preserve a physical "feel" for the problem.

I understand that, in the United Kingdom, it has been recently recommended that undergraduates in all disciplines learn computing. The experience with the mini-computer has shown that students can learn to use a language effectively within a very few hours, mostly by themselves.

ACKNOWLEDGMENTS

The computer system was chosen and bought by Professors D. A. Lind and R. Ristinen under National Science Foundation Grant GY 4824. I am grateful to Robert Holzworth for much patient explanation.

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[3] J. E. Skelton, An Introduction to the BASIC Language, (Holt, Rinehart and Winston, New York. to be published April 1971). This more elementary text is written for the PDP-8/L computer. I am grateful to Dr. Skelton for a copy of the test version.

[4] Introduction to Programming (Digital Equipment Corp., Maynard, Mass., 1969), Chapt. 9 (now replaced by Programming Languages, Chap. 11). One wishes that most physics texts were as well written.

[5] P. R. Bevington, Data Reducation and Error Analysis for the Physical Sciences, (McGraw-Hill, New York, 1969).

[6] Model TP 1351, Tennecomp Systems, Inc., Oak Ridge, Tennessee.

[7] A. Pope, Essay on Criticism, (W. Lewis, London, 1713). Part II.